Chapter 34

THE PERFORMANCE OF AUTOMATIC SPRINKLER SYSTEMS IN THE EXTINGUISHMENT OF INCIPIENT CONVEYOR BELT FIRES UNDER VENTILATED CONDITIONS

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The U.S. Bureau of Mines conducted a study to evaluate the effectiveness of automatic water sprinkler systems in the extinguishment of incipient conveyor belt fires under ventilated conditions. Large-scale experiments were conducted using a double strand conveyor belt configuration. Standard response, pendent-type sprinklers, with activation temperatures of 100 °C, were installed above and between the two strands of belting, in accordance with Federal standards for sprinkler system installations in belt drive areas. Experiments at airflows of 1.1 and 4.6 m/s showed that the sprinklers activated later, the peak heat release rate was larger, and more belting was consumed at the higher airflow. In experiments with 74 °C, fast response, directional sprinklers, the sprinklers activated at the same heat release rate for both high and low airflows, but the peak heat release rate and amount of belt consumed was slightly higher at the lower airflow. Experiments were also conducted with 100 °C, standard pendent sprinklers installed above the top belt, in accordance with the National Fire Protection Association (NFPA) Standard 123 for sprinkler system installations in conveyor belt drive areas in underground coal mines. In these experiments, the heat release rate and amount of belting consumed was larger at the higher airflow.

INTRODUCTION

Underground coal mine fires are a serious threat to life, property, and the Nations's mineral resources. A study by Timko (1993) reported that between 1970 and 1989, the Mine Safety and Health Administration (MSHA) investigated 298 coal mine fires, and that 56 of the fires (19 pct) occurred in belt entries. In 1988, a conveyor belt fire that started in the drive area spread rapidly through the Marianna No. 58 Mine, Pennsylvania, and the entire mine had to be sealed (Strahin, et al, 1990).

Federal regulations for underground coal mines (1991) require that either automatic sprinkler systems, deluge-type water spray systems, foam generators, or dry powder chemical systems be installed at all main and secondary conveyor belt drive areas. The standards state that if water sprinkler systems are used, the components shall be installed, as far as practical, in accordance with the recommendations set forth in National Fire Protection Association 1968-69 edition, Code No. 13, "Installation of Sprinkler Systems." NFPA-13 provides the minimum requirements for the design and installation of water sprinkler systems. However, NFPA-13 does not consider the effect of ventilation on the activation characteristics or water distribution patterns of the sprinkler.

Warner (1974) showed that sprinkler systems were effective in extinguishing incipient conveyor belt fires at airflows up to 1.8 m/s. Recent research by the USBM showed that higher ventilation airflows can have a significant effect on the water discharge patterns of automatic sprinklers (Smith, et al, 1993). Another study showed that as the airflows were increased, the time to activate the sprinklers for a given heat release rate increased. At higher airflows, the highest air temperatures were shifted downstream from the fire, so that a fire directly under a sprinkler might not activate the sprinkler above it (Smith, et al, 1994).

In this report, the effectiveness of automatic sprinkler systems to extinguish incipient conveyor belts fires at different airflows was evaluated. Experiments were conducted at airflows ranging from 1.1 to 4.6 m/s, to examine the effects of ventilation, sprinkler type, and installation design on the extinguishment of incipient conveyor belt fires. This study supports the USBM's goal to improve safety in the mining industry.

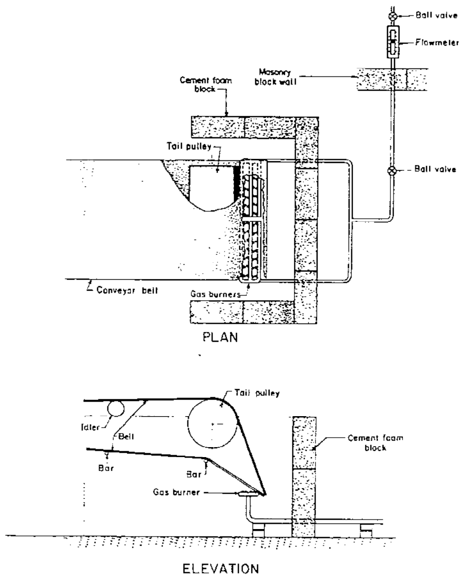

Figure 2. SCHEMATIC OF BELT IGNITION AREA

RESULTS AND DISCUSSION

Sprinklers Installed in Accordance With Federal Standards

In the experiment at the 1.1 m/s airflow with 100 °C, standard response, pendent sprinklers, the burners were turned off at 6.5 min, at a heat release rate of 0.35 MW, as shown in figure 3. The heat release rates were calculated by two different methods, based on measurements of the CO and CO_2 produced (Egan, 1993), and the amount of O_2 consumed (Tewarson, 1980 and Parker, 1982). The average of these two methods is reported as the heat release rate in all the extinguishment experiments. The heat release rate fell briefly and then increased. The sprinkler directly above the center of the tail pulley opened at 9.5 min, at a heat release rate of 0.45 MW. The maximum CO and CO_2 concentrations, and minimum O_2 concentration, were also observed at 9.5 min, 625 and 6,200 ppm, and 19.9 vol pct, respectively. The ambient O_2 concentration is 20.9 vol pct. These data are shown in table 1. The heat release rate continued to climb, reaching a maximum or 1.0 MW at 11.5 min. The water discharge from the one opened sprinkler above the tail pulley prevented the flame from propagating out of the ignition area, with just 0.9 m of the top belt and 1.5 m of the bottom belt consumed, as measured downstream from the centerline of the tail pulley. No other sprinklers activated.

In the experiment at 4.6 m/s the gas burners were turned off at 7.5 min. The heat release rate, shown in figure 3, was 0.6 MW. At 8.0 min, the sprinkler located between the belts, 2.4 m downstream, activated. The heat release rate observed at that time was 1.3 MW, downstream CO and CO_2 concentrations were 190 and 1,700 ppm, respectively, and the O_2 concentration was 20.4 vol pct. The heat release rate continued to rise, reaching 3.6 MW at 11 min. At that time, the water spray effectively stopped flame propagation along the bottom belt at 1.2 m. The bottom belting near the tail pulley continued to burn for about 3 min after the flame propagation was stopped, before being consumed. During that time, the burning bottom belt ignited the top belting. The top belt fire then propagated approximately 2.5 m, at a rate of 1.2 m/min. Flame propagation along the top belt was stopped by the water spray from the opened sprinkler between the belts. Before the top belt propagation was stopped, the heat release rate reached a peak of 3.7 MW, and a minimum O_2 concentration of 19.85 vol pct at 16 min. The peak CO and CO_2 concentrations, 540 and 5,000 ppm, respectively, occurred during the propagation of the bottom belt, at 11 min. None of the sprinklers above the top belt opened in this experiment.

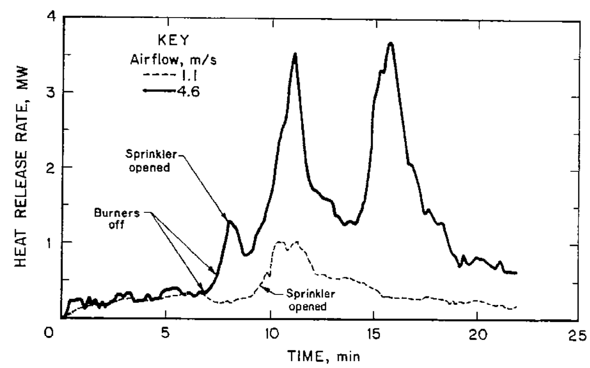

Figure 3. HEAT RELEASE RATES FOR FIRE TESTS WITH 100 °C, STANDARD RESPONSE SPRINKLERS ABOVE AND BETWEEN THE BELTS

The data indicated that the heat produced by the ignition of the bottom belting was sufficient to activate the sprinkler between the belts, limiting flame propagation along the bottom belt. However, the higher airflow had a cooling effect on the sprinklers located above the belt, preventing the sprinklers above the top belt from opening.

In these experiments, the sprinkler system effectively controlled and extinguished the incipient conveyor belt fires at both the 1.1 and 4.6 m/s airflows. In the experiment at the lower airflow, the sprinkler located above the tail pulley was the first to activate. This sprinkler was able to prevent flames from propagating out of the ignition area. As a result, just 0.9 m of the bottom belt and 1.5 m of the top belt was consumed. At the higher airflow, the sprinkler located between the belts, 2.4 m downstream was the first to open. This resulted in 2.5 m of the top belt being consumed before the water

Sprinklers Installed in Accordance With NFPA Standards

In the experiment conducted at the 1.3 m/s airflow, the burners were turned off at 8 min. The heat release rate, shown in figure 5, was 0.5 MW. The belt thermocouples indicated that the fire had not yet propagated out of the ignition area. The sprinkler directly above the center of the tail pulley activated at 8.25 min, at a heat release rate of 0.8 MW, and quickly extinguished the flames on the top belt. No other sprinklers activated. Flames on the bottom belt were able to propagate 1.8 m over the next 2 to 3 min, before water running off from the top belt stopped flame propagation. The peak heat release rate, 1.9 MW, maximum CO and CO_2 concentrations, 1,200 and 10,000 ppm, respectively, and minimum O_2 concentration, 19.4 vol pct, shown in table 1, were observed at 10 min. The 1.8 m of bottom belting continued to burn until consumed, as indicated by the decreasing heat release rate over the next 15 to 20 min.

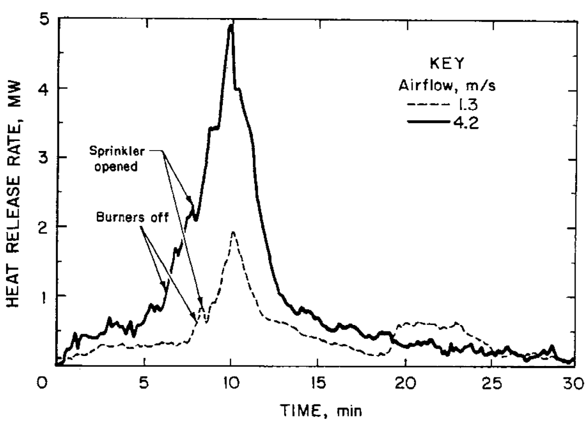

Figure 5. HEAT RELEASE RATES FOR FIRE TESTS WITH 100 °C, STANDARD RESPONSE SPRINKLERS ABOVE THE BELTS

In the experiment conducted at the 4.2 m/s airflow, the burners were turned off at 6.5 min, at a heat release rate of 1 MW. At 7.8 min, the sprinkler 3.0 m downstream opened. The heat release rate was 2.3 MW and the flames had propagated past the thermocouples located at 1.2 m on the top belt. The flames had not yet reached the thermocouple located 1.2 m downstream on the bottom belt. The water spray effectively stopped the flame propagation along the top belt at 2.0 m, and at 2.4 m along the bottom belt. At 10.5 min, the heat release rate peaked at 4.9 MW, CO and CO_2 concentrations peaked at 500 and 7,400 ppm, respectively, and the oxygen concentration dropped to a minimum of 19.9 vol pct. The heat release rate then dropped steadily as burning belt continued to burn until consumed.

Comparing the results of these experiments, the sprinkler system effectively controlled and extinguished the incipient conveyor belt fires at both the 1.3 and 4.2 m/s airflows. However, there were significant differences in the heat release rate required to activate the system, peak heat release rates, combustion gas concentrations, and amount of belting consumed. Probably the most significant difference observed was in the location of the sprinkler(s) that opened. In the experiment at 1.3 m/s, the sprinkler located directly above the tail pulley opened, at a heat release rate of just 0.8 MW. This limited fire damage to the top belt to just that belting that extended over the tail pulley into the ignition area. Approximately 1.8 m of the bottom belt was consumed before the fire on the bottom belt was extinguished. In the experiment at 4.2 m/s airflow, the first sprinkler to open was located 3.0 m downstream from the tail pulley, at a heat release rate of 2.3 MW. By that time, flames had begun to propagate along both the top and bottom belts. The fire propagated 2.0 m along the top belt and 2.4 m along the bottom belt before being stopped by the water spray from the sprinkler at 3.0 m.

Because of the increased amount of belting involved in the fire at the higher airflow, a significantly higher peak heat release rate was observed, 4.9 MW, compared to 1.9 MW at the lower airflow. Peak CO and CO_2 concentrations were higher, and the minimum oxygen concentration was lower at the 1.3 m/s airflow, since the higher airflow at 4.2 m/s acted to dilute the CO and CO_2 concentrations and increase the O_2 concentration.

Comparison of Sprinkler Configurations

Experiments were conducted using 100 °C, standard response, pendent sprinklers installed according to Federal regulations for sprinkler installations in belt drive areas, where the sprinklers were installed above and between the belts on 2.4 m centers, and according to NFPA guidelines for sprinkler installations in underground bituminous coal mines, where the sprinklers were installed only above the top belt, on 3.0 m centers. The experiments were conducted at airflows of 1.1 and 1.3 m/s and 4.2 and 4.6 m/s, respectively.

In the experiments at the lower airflows, the sprinkler located directly above the tail pulley was the only sprinkler to activate in both design installations. As shown in table 1, the sprinkler was able to control and extinguish the fires, with limited belt damage. In the experiment at the higher airflows, using the design with sprinklers located above and between the belts, the sprinkler located between the belts, 2.4 m downstream activated at a heat release rate of 0.4 MW. This sprinkler alone was able to control and extinguish both the top and bottom belt fires.

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